FINAL REPORT FOR JOINT VENTURE AGREEMENT NO. 00-JV-11221615-218 LONG-TERM RESPONSE OF VEGETATION TO MANAGEMENT ON THE SANTA RITA EXPERIMENTAL RANGE

Maureen A Stuart
10/03/2005 11:45 AM

To: rmrs agreements@FSNOTES
cc: Maureen A Stuart/RMRS/USDAFS@FSNOTES
Subject: Fw: final report for 00-JV-11221615-218 UA (McClaran)

Attached please find the final report for this project along with a technical report for the entire JVA.
Thanks, Maureen

final report 04-05 original project.rtf

technical report for Joint Venture Agreement.rtf

TO: RMRS Library

30 September 2005

Final Report
00-JV-11221615-218

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Dear Carl:

Please consider the enclosed Final Report for the original work identified in the Joint Venture Agreement No. 00-JV-11221615-218 entitled *Long-Term Response Of Vegetation To Management On The Santa Rita Experimental Range.*

As you will see in the formal (abbreviated) report and the accompanying more technical report , we completed all the proposed tasks, and now have the makings of a very good PhD dissertation for one of my students, Fadzayi Mashiri. She is a Fullbright Fellow from Zimbabwe and she has done a superb job with the "hard look" an the Santa Rita Grazing System research. We have plans to expand the work reported here to include some analysis of co-variance with precipitation, and to take much closer look at the responses of individual species. I expect her to complete her degree and have submitted manuscripts for publication by June 2006.

With this Final Report and the Final Report for the amendment (under separate cover), this Joint Venture Agreement is now completed. We learned a great deal about some basic ecology and management, and have moved the management and access of the Santa Rita archive into the 21st Century. For example, the Santa Rita Digital Database is now part of a much larger group of ecological databases that are delivered under the name of "Knowledge Network for Biocomplexity" being managed by the National Center for Ecological Analysis and Synthesis. If you access their website at http://knb.ecoinformatics.org/index.jsp and search by Santa Rita Experimental Range, you will see links to our database. This is very exciting because it brings us in contact with ecologists from around the world, and informs them about the many resources, both virtual and electronic, that are available at the Santa Rita.

My efforts are now moving to perform work related to the new Joint Venture Agreement No. 05-JV-11221615-6077 titled "Continuation of Long-Term Vegetation Measurement and Repeat Photography on the Santa Rita Experimental Range". We have everything, people and resources in place to complete the re-measurement of the permanent transects and placement of those measures on the website by the end of May 2006.

Continued efforts for that Agreement include the re-photography at the permanent photo stations in 2007. You suggested that I remind you that we will need to add funding to this Agreement in order to complete the re-photography work in 2007. I will call next week to follow-up on the possibility of gaining funding for these efforts.

Sincerely,

Mitchel McClaran
Professor of Range Management
Director of Research, Santa Rita Experimental Range

Enclosures

Final Report for Joint Venture Agreement No. 00-JV-11221615-218

Long-Term Response Of Vegetation To Management On The Santa Rita Experimental Range

Prepared by
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30 September 2005

Background:

The purpose of this agreement is to analyze the consolidated, long-term vegetation measurement archives available for the Santa Rita Experimental Range, Arizona, in order to describe the responses of vegetation to management practices over periods of >40 years.

Established in 1903, Santa Rita Experimental Range (SRER) is the oldest range experiment station in the world. Initially, the U.S. Department of Agriculture, Bureau of Plant Industry were the primary organizations conducting research on the SRER, and later the Forest Service in cooperation with the University of Arizona. Federal legislation in 1988 transferred the SRER to the Arizona State Land Department and Arizona Senate Bill 1249 (38th Legislature) provided that the area would be used by the University of Arizona for, "ecological and rangeland research purposes..... until such time as the legislature determines the research use can be terminated on all or part of the lands."

Because written records of climate, vegetation change, livestock use and land use treatments as well as repeat photography have been collected on SRER since 1903, this database provides a long term record that is unsurpassed in the Southwest or the world.

The records include a combination of weather records; plant species composition measurements on more than 200 permanent plots; extensive land treatment studies; short term, usually small scale tests or observations; and over 110 permanent photography stations.

Objectives:

The specific objective of this is amendment is to evaluate the application of the Santa Rita Grazing System on the Santa Rita Experimental Range (SRER) from 1972-2003. This specific objective will include procedures that re-evaluate data analyzed by Martin and Severson (1988, J. Range Manage. 41: 291-295) following 12 years of applying the grazing system, and new analyses of data collected in the 20 years since their initial analysis.

This effort should provide valuable information on the long-term effects of the seasonal rotation grazing system, and the importance of statistical analysis methods on the apparent results.

Procedures:

1. Compile all data used by Martin and Severson (1988) in their analysis of the grazing system from 1972-1984. These data include livestock stocking rate, perennial grass utilization rates, perennial grass productivity, cover by plant species, and density by plant species. Format these data for statistical analysis.

2. Compile all data gathered from 1991-2003 from the same locations used by Martin and Severson (1988). These data include livestock stocking rate, cover by species, and density by species. Format these data for statistical analysis.

3. Assess the amount of deviation in grazing management and sample measurements obtained during the initial study periods of 1972-1984 and the later period of 1991-2003. Possible deviations may include differences in stocking rate, rotated pastures, and number of sample transects.

4. Develop the most logical and reliable adjustments to the study design and statistical analyses needed to account for the possible deviations in grazing management and sample measurements discovered in procedure #3.

5. Repeat analysis performed by Martin and Severson (1988). They used a simple split plot analysis of variance with years as subplots. This analysis would be performed on the 1972-1984 data, the 1991-2003 data, and the entire data set from 1972-2003. The study design will include the sets of comparisons and analytical approaches determined in procedure #4. Results will be compared to results presented by Martin and Severson (1988).

6. Perform different statistical analysis than those used by Martin and Severson (1988) to evaluate the issues of non-normally distributed data, lack of homogeneous variance, lack of independence among different sampling years, and significant interactions among independent variables. Tests for normality and equal variance will be performed, and appropriate transformations or adjustments will be made. Repeated measures analysis of variance and general linear model methods will be applied to account for lack of independence among years. Emphasis will be placed on interactions between independent variables, and main effects will be considered important only if interactions are not significant. These analyses will be performed on the 1972-1984 data, the 1991-2003 data, and the entire data set from 1972-2003. Results will be compared to results presented by Martin and Severson (1988).

Timetable for Accomplishing Procedures:

	DATE											
	2004									2005		
Procedure	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	X	X										
2		X	X									
3			X	X								
4				X	X							
5						X	X	X	X			
6									X	X	X	X

Status of Procedures:

1. Compile all data used by Martin and Severson (1988) in their analysis of the grazing system from 1972-1984. These data include livestock stocking rate, perennial grass utilization rates, perennial grass productivity, cover by plant species, and density by plant species. Format these data for statistical analysis.

   These data have been compiled and formatted for statistical analysis. They exist as excel files that are compatible with statistical software such as JMP and SAS.

2. Compile all data gathered from 1991-2003 from the same locations used by Martin and Severson (1988). These data include livestock stocking rate, cover by species, and density by species. Format these data for statistical analysis.

   These data have been compiled and formatted for statistical analysis. They exists as excel files that are compatible with statistical software such as JMP and SAS.

3. Assess the amount of deviation in grazing management and sample measurements obtained during the initial study periods of 1972-1984 and the later period of 1991-2003. Possible deviations may include differences in stocking rate, rotated pastures, and number of sample transects.

   This work is completed. Deviations from the original study include livestock management in two of three blocks, and discontinuation of some vegetation measurements.

   During the compilation of these data, we learned that there were deviations from the procedures described in the original Study Plan prepared by S.C. Martin, and the publication by Martin and Severson (1988). Specifically, these deviations were in 1) the assignment of pastures to seasonal-rotation treatments and 2) the assignment of specific plant species to the "woody" plant category.

   The original study included three blocks where the grazing treatments of year-round and rotation of seasonal grazing were applied within each block. Beginning in 1985, these treatments were discontinued in the upper-elevation block in order to initiate and new investigation on High Intensity-Low Frequency grazing management (UA Cell). In the early 1990s, there was some confusion in the assignment of pastures to year-round rotation of seasonal grazing treatments in the mid-elevation block, and therefore the continuity of these treatments was

compromised in one of three Santa Rita rotation pastures in the middle elevation block. Nonetheless, between 1984 and 2003, the grazing management in the low-elevation block was performed in a manner consistent with the original study.

Species cover and density, herbaceous production and utilization by livestock were measured on each transect between 1972 and 1984. From 1991-2003, measures of species cover and density were continued, but those of herbaceous production and utilization were not completed.

In summary, the deviations in executing the treatments have reduced the number of blocks from 3 to 2. The deviations in performing the measurements have reduced the response variables to species cover and density.

4. Develop the most logical and reliable adjustments to the study design and statistical analyses needed to account for the possible deviations in grazing management and sample measurements discovered in procedure #3.

   This work is completed. In the long term analysis (1972-2003) we will limit our response variables to species cover and density, and we will limit our examination of these to the middle and low elevation blocks of treatments.

5. Repeat analysis performed by Martin and Severson (1988). They used a simple split plot analysis of variance with years as subplots. This analysis would be performed on the 1972-1984 data, the 1991-2003 data, and the entire data set from 1972-2003. The study design will include the sets of comparisons and analytical approaches determined in procedure #4. Results will be compared to results presented by Martin and Severson (1988).

   This work is completed. We have been able to re-create the raw results reported in Martin and Severson (1988) for most response variables, and understand how their analytical methods can be improved.

   After a good deal of effort, we were finally able to rectify the assignment of pastures to treatments and species to "herbaceous" plant group, but the assignment of species to the "woody" plant category has eluded us so far.

   Using a split-plot design, with year as the split, we were able to re-create the results reported in Martin and Severson (1988) for all response variables except some woody plant categories. In particular, we have not been able to re-create the values reported for woody plant density for total woody plants and

prickly pear cactus. We have been able to re-create results for the most common woody species which are burroweed, calliandra, cane cholla and velvet mesquite. Therefore, the source of the problem appears to reside in the assignment of relatively rare species to the "prickly pear" and "other woody species" categories.

6. Perform different statistical analysis than those used by Martin and Severson (1988) to evaluate the issues of non-normally distributed data, lack of homogeneous variance, lack of independence among different sampling years, and significant interactions among independent variables. Tests for normality and equal variance will be performed, and appropriate transformations or adjustments will be made. Repeated measures analysis of variance and general linear model methods will be applied to account for lack of independence among years. Emphasis will be placed on interactions between independent variables, and main effects will be considered important only if interactions are not significant. These analyses will be performed on the 1972-1984 data, the 1991-2003 data, and the entire data set from 1972-2003. Results will be compared to results presented by Martin and Severson (1988).

This work is complete, and greater details are available in the accompanying technical report "

Results from the comparison of raw versus ranked data show the importance of upholding the assumption of normality. Analysis based on non-normal data is likely to result in wrong inferences being reached thereby making either type I or type II errors.

Results from applying the repeated measures analysis, that accounted for the lack of temporal independence among the measures from permanent transects, revealed important interactions among the grazing treatment, block and time main effects. Interestingly, in the original reporting of these data, Martin and Severson ignored the issue of lack of independence, and failed to account for interactions among the main effects. As a result of these oversights, they misrepresented the vegetation dynamics as responding simply to grazing system, block, or time. In contrast, our analysis revealed that the norm was for significant 2-way and 3-way interactions among main effects.

The three-way time by block by grazing treatment interaction shows evidence of both grazing system and spatial differences associated with blocks as important factors in determining plant dynamics on the SRER. Because blocking was based on different precipitation zones in the area, this three way interaction also implies that precipitation influences plant dynamics on the SRER. Although results showing interactions are more difficult to interpret and apply in a management setting, they are more realistic and supportable because they do a better job of representing the nature of vegetation dynamics.

The fewer degrees of freedom that result when psuedoreplication is avoided reduced the power to detect differences in the vegetation dynamics that can be associated with either grazing treatment or block. In fact, with one exception, only the simple effect

of time was related to vegetation dynamics when psuedoreplication was avoided. As a result, the strongest inference from this study, that which can be supported by the statistical analysis and proper representation of the experimental unit, is 1) on areas similar to the study pastures, either on the SRER or in similar environments, vegetation dynamics will be related to temporal fluctuations, and not the application of the SR grazing system or the environmental differences among the 3 blocks of pastures, and 2) within the confines of the 12 study pastures, vegetation dynamics are related to the 2 and 3-way interactions among grazing system, block, and time rather than simple, solitary relationships with the factors.

Management decisions based on such unsupported inferences in fragile semi-desert ecosystems could have serious undesirable ecological implications, and undermine confidence in scientific investigations. While the application of complicated statistical analysis may paint a less tangible picture of vegetation response to management practice, they are much preferred to a false sense of security that may come from overly simple and incorrect statistical analysis.

The availability of long term data greatly improved the understanding of the plant dynamics. Results from the short term study indicated a continuous gradual decline in perennial grass density and increasing shrub cover over time. However after 32 years of the experiment evidence of fluctuating grass density which is likely to be responding to climatic changes and some gradual decrease or stabilizing of shrub cover are emerging. Long term data is valuable in semi-arid ecosystems where response to management is likely to be slow and environmental variables become important driving factors of the ecosystem dynamics.

Technical Report
00-JV-11221615-218

Effects of yearlong and seasonal rotational grazing on plant species composition on the Santa Rita Experimental Range.

Technical Report for Joint Venture Agreement No. 00-JV-11221615-218 entitled *Long-Term Response Of Vegetation To Management On The Santa Rita Experimental Range.*

Principal investigator: Mitchel McClaran

Research Assistant: Fadzayi E. Mashiri

30 September 2005

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1. Introduction

1.1. Grazing management theory

Grazing management involves determining the optimal grazing intensity, stocking rates, timing and duration of grazing for the health of the rangeland and the herbivores (Heady and Child, 1994). A grazing system is a specialized form of grazing management that employs alternate periods of grazing, deferment and rest in at least 2 pastures (Society for Range Management, 1989).

Rotational grazing systems are expected to improve seed production and establishment rates, abundance of palatable species, herbivore distribution, uniformity in forage utilization and rangeland condition (Heady, 1961). Yearlong (YL) grazing is thought to lack the sufficient periods of rest from defoliation to facilitate vegetation regrowth and compromises rangeland productivity by encouraging selective and patch grazing particularly in large grazing allotments (Teague and Dowhower, 2003). The low stocking densities in YL grazing, however, permits selective grazing at species and plant levels, resulting in higher average daily weight gains per animal (Jennings, 2004). Developing rotational grazing systems that do not reduce long term stocking rates are based on the assumption that periodic high intensity grazing with sufficient rest allows maintenance or even improvement of vegetation condition because; i) rest allows similar or greater vegetation recovery from periods of intensive defoliation compared to continuous moderate defoliation (Teague *et al*, 2004) and ii) the high stocking density reduces selective grazing that in turn decreases the competitive advantage of less preferred species (Kirkman and Moore, 1995, Norton, 1998).

Rotational grazing can result in greater increases in basal area and lower proportions of bare ground compared to continuous grazing in a semi-arid ecosystem (Teague *et al*, 2004). Spring-summer rest promotes establishment and persistence of warm season plant species because they are protected at the period of maximum growth and may also improve the reproductive rate of cool season species that establish in fall (Hidalgo and Cauhepe, 1991). However seasonal grazing in a Mediterranean climate dominated by annuals produced no significant differences in primary production and

plant cover between areas under spring and continuous grazing, while fall grazing reduced foliar cover and the number of taxa in the community (Bartolome and McClaran, 1992).

There are few empirical studies supporting the proposition that the periodic high grazing intensity of rotational grazing systems is a remedy for deteriorating rangelands (Kirkman and Moore, 1995, Norton, 1998) through the avoidance of selective grazing that occurs in continuous YL grazing systems (Teague and Dowhower, 2003). However, the evidence of effects of rotational grazing on defoliation patterns is weak (Norton, 1998). Norton (1998) cites the reasons for more uniform utilization in rotational grazing systems to be the use of small homogenous pastures that reduce patch grazing (Norton. 1998), rather than the rotation itself.

Both grazing intensity and grazing season may influence the seed bank, root mass, residual leaf area and meristematic tissue, which in turn influence future recruitment, growth and persistence. Although young leaves produced by plants as they regrow after grazing events have high photosynthetic efficiency (Parsons *et al.*, 1983), the benefits are limited because of increased dependence on photosynthetically-inefficient leaf sheath as grazing intensity increases (Chapman and Lemaire, 1993; Parsons *et al.*, 1983; Mathew *et al*, 2000). The season of grazing relative to the progression of the phenological development of the different species can play a major role in determining the competitive interaction of species and the future species composition (Briske, 1991).

Rotational grazing is often proposed as a solution to rangeland degradation, but the responses of vegetation have not always been consistent, over space and time. It is becoming more and more apparent that many factors interact to influence vegetation dynamics (Milchunas *et al.*, 1994; Fynn and O'Connor, 2000). Vegetation attributes measured, spatial scale, precipitation, soils, type of herbivores, vegetation type and resilience to grazing are some of the factors cited. The analysis of studies investigating effects of grazing systems must include factors that add variation that is 'too noisy to discern effects of grazing' (Milchunas *et al.*, 1994) or control those factors. When the influences of treatments have not been observed, interpretations of vegetation responses to grazing systems have enlisted numerous factors beyond the grazing treatment to

interpret the results. Precipitation patterns and vegetation that is insensitive to grazing are examples of these enlistments.

1.2 Opportunities available at the Santa Rita Experimental Range for studying seasonal rotational grazing

The Santa Rita (SR) grazing system is a three-pasture 1-herd seasonal rest rotation system, with a three year grazing cycle. Each of the three pastures has two grazing periods; March to October (fall) and November to February (spring-summer), with 12 months of rest after every grazing period (Martin and Severson, 1988). This sequence of grazing and rest has been evaluated before, once in plots and then in pastures (Martin, 1973; Martin and Severson, 1988).

The pasture level trial, the SR and yearlong grazing systems were compared, starting in 1972, and used a randomized block design with three blocks based on elevation was used (Martin and Severson, 1988). The blocks represented different biotic communities (Brown, 1994) and spatial differences in average annual precipitation over the landscape. The pastures grazed under the SR grazing system were grouped into three grazing treatments, SR1, SR2 and SR3 based on their starting point of grazing along the rotational grazing scheme. Therefore each block consisted of four pastures; one grazed YL and three experiencing rotational grazing. Martin and Severson (1988) found differences between yearlong and season-rotation treatments but the differences varied over blocks and grazing treatments over time, and presumably their interactions.

A critical evaluation of the approach used by Martin and Severson (1988) reveals possible areas for improving analysis. Improvements can be achieved by ensuring that the assumptions of normality and homogeneity of variance are met; non-independence of samples over time is accounted for, and pseudoreplication is avoided. Upholding the assumption of normality reduces the risk of committing either a Type I or Type II error. Martin and Severson (1988) used the split-plot analysis, using years as subunits. This procedure assumes that the subunits are independent (Wilm, 1945), which is not the case with time series data. To correct for the problem of non-independence between time series data, we used repeated measurements analysis of variance.

Martin and Severson (1988) performed mean comparisons using transect estimates, not pasture averages thereby introducing pseudoreplication because the transects were sub-samples of the pastures. This psuedoreplication limits the application of findings to only the pastures on the SRER included in this study. In contrast, if psuedoreplication was avoided, by making the pastures the sample unit rather than the transects, one could apply the findings to other similar rangelands on the SRER and beyond. The avoidance of psuedoreplication will require the use pasture averages based on the transects in a pasture, and would result in many fewer replicates than the 120 transects used by Martin and Severson.

The availability of longer term data is an opportunity to identify trends that could have been obscured by environmental fluctuations during the shorter period and the difference between the response variables could have accumulated over time to detectable levels.

Analysis will be divided into two time periods, the first 12 years (1972-1984) and the 32-year period (1972-2003). The first period is the same period that was evaluated by Martin and Severson (1988). Using the same data as Martin and Severson (1988) enables comparison of their results with ours. This will give an insight into how upholding statistical fundamentals; normality, homogeneity of variance, sample independence, and avoiding pseudoreplication could affect the results. We only used a sub-set of the pastures in the long term analysis because some of the pastures had the grazing systems protocols changed after 1984.

2. Research Objectives

The overall goal of this study is to compare the effects of yearlong and seasonal rotational grazing systems on plant dynamics over time. I will evaluate how 12 years and 32 years of grazing and resting in different seasons, as applied through the SR grazing system, affected plant density and cover of selected plant species and functional groups.

2.1. Evaluate how normality and independence of data influence the results comparing the YL and SR grazing system treatments effects on plant density and cover.

2.2. Evaluate the effects of pseudoreplication on detecting differences between the grazing system treatments.

2.3. Compare results of short term grazing period to Martin and Severson (1988) results, to evaluate the effects of upholding the assumptions of normality and sample independence, avoiding pseudoreplication and accounting for interactions.

3. Methods

3.1. Grazing Treatments and Response Variables

The SR and YL grazing systems have been on trial at the SRER for 32 years, starting in 1972. A randomized block design with three blocks based on elevation was used (Martin and Severson, 1988). Elevation decreased from block I to III. Each block was composed of 4 pastures; 3 of which were grazed under the SR grazing system and one grazed yearlong. Each of the three SR grazing system pastures was grazed twice during the 3 year grazing cycle; between March and October (fall) and November through February (spring-summer), with 12 months rest after each grazing season (Martin and Severson, 1988). Stocking rates were set at levels equivalent to the average number

of animal units that would utilize 40% of perennial grass biomass produced during the period 1959 through 1968 (Martin and Severson, 1988). Stocking rates and grazing periods were adjusted during drought to minimize overgrazing. Pasture sizes ranged from 308 to 2146 hectares. The pastures in the different blocks were Block I (8, 21, 1, 22), Block II (2N, 6A, 2S, 6B), and block III (5N, 5S, 3, 12B), arranged in the order YL, SR1, SR2 and SR3 respectively.

The long-term comparison of the YL and SR grazing systems as defined by Martin and Severson (1988) is only possible if the protocols started in 1972 were followed consistently throughout the 32-year period. However starting in 1984, deviation occurred in stocking rates and grazing schedules in some pastures. Pastures that will be used to investigate the long-term response of vegetation to the grazing treatments and systems did not experience severe deviations from the grazing schedule and stocking rates protocols used in 1972 through 1984. The pastures are 5N (YL), 5S (SR1) and 3 (SR2) in Block II and pastures 2N (YL), 6A (SR1), 2S (SR2) and 6B (SR3) in Block III.

The plant measurements were made in ten transects per pasture, bringing the total to 120 transects (12 pastures) between 1972 and 1984 (Martin and Severson, 1988) and 70 transects (7 pastures) for the 32-year period. Intensive sampling where data was collected in 10 sub-sample units per pasture improves interspersion of samples within an experimental unit.

Except for basal cover measurements of grass species that started in 1984, density and cover were measured every three years for the period 1972 through 1984 and 1991 through 2003 (Martin and Severson, 1988, McClaran *et al.*, 2002). Both cover and density were recorded for each perennial plant species, except for some species that were combined into genera because of identification difficulties in the field.

The 3-yr interval of cover and density measurements matched the grazing cycle of the Santa Rita grazing system, and therefore some correlations may arise due to this synchrony. To proceed with the study however I made an assumption that density and basal cover, unlike biomass are fairly stable attributes (Elzinga *et al.*, 1998) that would not be influenced heavily by the current season's grazing treatment making them good measures of long term trends.

We converted the numbers of plants of selected species and functional groups per 0.305 x 30.5m belt transect to plants/m^2 by dividing by 9.29. We then calculated average densities of the respective species and functional groups per pasture using the 10 transect densities were calculated. Basal cover and canopy cover were measured for grass species and woody species respectively. The line intercept method (Canfield, 1941) was used to measure basal and canopy cover on a 30.5-meter line transect. The functional groups we used were perennial grasses, native grasses, and shrubs and cacti. I analyzed the cover and density of Lehmann lovegrass (non-native grass species), Arizona cottontop, Rothrock grama, velvet mesquite, calliandra, burroweed, prickly pear, and cholla species.

3.2. Data Analysis

3.2.1. Effects of normality, independence and pseudoreplication on comparing vegetation response among YL, SR1, SR2 and SR3.

We performed the Shapiro-Wilk W-test for normality (Shapiro and Wilk, 1965) and the Brown-Forsythe test for homogeneity of variance (Sall and Lehman, 1998) on plant density and cover of YL, SR1, SR2 and SR3 grazing treatments. None of the variables was normally distributed, with most data sets being skewed to the right. We ranked the data to correct for non-normality. Only two variables had their variances slightly unequal and we decided that homogeneity of variance was not a problem.

We performed repeated measurements analysis of variance on both transect estimates and pasture averages of plant density and cover. We used average cover and density per pasture of the respective species or functional groups to avoid pseudoreplication. We compared the results of the short term period to Martin and Severson, (1988) results to assess the effects of independence of samples, accounting for interactions and pseudoreplication. We used JMP IN 5.1 statistical package for data analysis, using a P-value <0.05 to identify differences. We performed the Tukey-Kramer means comparison method to assess if the means of density or canopy cover are different over time, blocks or treatments. We compared P-values from analyses done using raw

therefore non-normal data and ranked data to assess effects of normality in detecting differences between treatments.

4. Results

4.1 The effects of ranking on detecting differences between changes in plant density and cover of 4 grazing treatments (GT) during the short term (1972-1984) and long term (1972-2003) grazing periods.

To understand the effect of normality, the results from repeated measurements analysis using raw data were compared to those obtained using ranked data. The comparison revealed that the majority (35) of the significant highest level interactions were consistent between data sets, but 20 differed (Tables 1 and 2). Of the 34 (17 species and functional groups and 2 time periods of short and long term each) response variables, 10 variables had different results for raw and ranked data. Of these 10 response variables, seven Type I errors (e.g. long term shrub density, short term burroweed density, short term calliandra density) and four Type II errors (e.g. long term density of Rothrock grama and calliandra) could have been committed if the analysis was based on raw data because it was not normally distributed. Type I error occurred where higher level interactions were found significant with raw but not by ranked data and Type II error was committed when significant differences detected by ranked data were missed when raw data was used.

Table 1. The P-values from the repeated measurements (RM) analysis of raw and ranked data of plant density for 4 grazing treatments over the short and long-term grazing periods.

Functional group/ species	Period of study	Type of data	Terms in repeated measurements analysis model						
			Time (T)	Grazing treatment (GT)	Block (BL)	BL*GT	T*BL	T*GT	T*BL*GT
Perennial grasses	Short term	Raw	0.006	0.671	<0.001	0.001	<0.001	0.001	0.001
		Ranked	<0.001	0.399	<0.001	<0.001	<0.001	<0.001	<0.001
	Long term	Raw	<0.001	0.003	0.027		0.006	<0.001	
		Ranked	<0.001	0.007	<0.001		0.001	<0.001	
Native grasses	Short term	Raw	<0.001	0.092	0.001	0.001	<0.001	0.002	<0.001
		Ranked	<0.001	0.010	<0.001	<0.001	<0.001	<0.001	<0.001
	Long term	Raw	<0.001	<0.001	0.091		<0.001	<0.001	
		Ranked	<0.001	<0.001	0.166		<0.001	<0.001	
Arizona cottontop	Short term	Raw	<0.001	0.031	<0.001	0.234	<0.001	0.004	0.150
		Ranked	<0.001	0.186	<0.001	0.040	<0.001	0.029	0.119
	Long term	Raw	<0.001	0.139	0.306		0.036	0.002	
		Ranked	<0.001	0.389	0.193		0.001	0.004	
Rothrock grama	Short term	Raw	<0.001	0.018	0.252	0.012	0.001	0.062	0.001
		Ranked	<0.001	<0.001	0.040	0.031	<0.001	0.021	0.038
	Long term	Raw	<0.001	0.001	0.080		0.059	0.004	
		Ranked	<0.001	<0.001	0.189		0.003	<0.001	
Non-native grasses	Short term	Raw	<0.001	0.037	<0.001	0.291	<0.001	0.137	0.002
		Ranked	<0.001	<0.001	<0.001	0.018	<0.001	0.521	0.005
	Long term	Raw	<0.001	<0.001	<0.001		<0.001	<0.001	
		Ranked	<0.001	<0.001	<0.001		0.021	<0.001	
Lehman lovegrass	Short term	Raw	<0.001	0.042	<0.001	0.303	<0.001	0.146	0.003
		Ranked	<0.001	0.020	<0.001	<0.001	<0.001	0.480	0.001
	Long term	Raw	<0.001	<0.001	<0.001		<0.001	<0.001	
		Ranked	<0.001	<0.001	<0.001		<0.001	<0.001	
Shrubs	Short term	Raw	<0.001	0.854	0.001	0.001	<0.001	0.262	<0.001
		Ranked	<0.001	0.027	<0.001	0.006	<0.001	0.036	0.002
	Long term	Raw	<0.001	0.880	0.024		<0.001	0.005	
		Ranked	<0.001	0.490	0.024		<0.001	0.224	
Burroweed	Short term	Raw	<0.001	0.423	<0.001	0.007	<0.001	0.011	<0.001
		Ranked	<0.001	0.221	<0.001	<0.001	0.001	0.002	0.487
	Long term	Raw	<0.001	0.643	0.009		0.001	<0.001	
		Ranked	<0.001	0.025	0.006		<0.001	0.007	
Calliandra	Short term	Raw	0.001	0.156	<0.001	0.008	<0.001	0.137	0.001
		Ranked	<0.001	0.411	<0.001	0.291	0.137	0.443	0.058
	Long term	Raw	0.136	0.254	0.056		0.657	0.177	
		Ranked	0.496	0.430	0.019		0.475	0.364	
Prickly pear	Short term	Raw	0.001	0.194	0.001	0.436	0.004	0.508	0.514
		Ranked	0.002	0.138	0.001	0.096	0.032	0.379	0.557
	Long term	Raw	<0.001	0.021	0.377		0.033	0.017	
		Ranked	<0.001	0.004	0.694		0.011	0.003	

Shading indicates highest significant interaction or main effect at 0.05 level of significance.

Table 2. The P-values from the repeated measurements (RM) analysis of raw and ranked data of plant cover for 4 grazing treatments over the short-term and long-term grazing periods.

Functional group/ species	Period of study	Type of data	Repeated measurements analysis model terms						
			Time (T)	Grazing treatment (GT)	Block (BL)	BL*GT	T*BL	T*GT	T*BL*GT
Perennial grasses[i]	Long term	Raw	0.017	<0.001	<0.001		<0.001	0.004	
		Ranked	<0.001	0.217	<0.001		<0.001	<0.001	
Shrubs	Short term	Raw	<0.001	0.261	0.913	0.009	0.515	0.187	0.028
		Ranked	<0.001	0.133	0.760	0.009	0.787	0.197	0.025
	Long term	Raw	<0.001	0.827	0.086		0.094	0.775	
		Ranked	<0.001	0.778	0.054		0.170	0.792	
Velvet mesquite	Short term	Raw	<0.001	0.656	0.403	0.003	<0.001	0.059	0.012
		Ranked	<0.001	0.392	0.025	<0.001	0.003	0.629	0.509
	Long term	Raw	<0.001	0.308	0.009		0.003	0.574	
		Ranked	<0.001	0.260	0.005		0.026	0.880	
Burroweed	Short term	Raw	<0.001	0.423	0.001	0.001	<0.001	0.011	0.072
		Ranked	<0.001	0.221	0.001	0.004	0.001	0.002	0.096
	Long term	Raw	<0.001	0.082	0.024		0.005	0.011	
		Ranked	<0.001	0.070	0.014		0.002	0.006	
Calliandra	Short term	Raw	<0.001	0.081	<0.001	0.069	0.001	0.001	0.001
		Ranked	<0.001	0.118	<0.001	0.222	0.178	0.167	0.375
	Long term	Raw	0.094	0.161	0.121		0.582	0.057	
		Ranked	0.138	0.086	0.044		0.576	0.164	
Cholla	Short term	Raw	0.575	0.106	0.605	0.839	0.494	0.271	0.025
		Ranked	0.629	0.147	0.270	0.403	0.943	0.045	0.362
	Long term	Raw	0.117	0.384	0.290		0.340	0.497	
		Ranked	0.164	0.621	0.153		0.109	0.078	
Prickly pear	Short term	Raw	0.164	0.944	<0.001	0.949	0.377	0.951	0.908
		Ranked	0.108	0.268	<0.001	0.140	0.565	0.654	0.957
	Long term	Raw	<0.001	0.040	0.149		0.102	0.020	
		Ranked	<0.001	0.001	0.821		0.001	0.249	

[i] Grass cover measurements only started in 1984
Shading indicates highest significant interaction or main effect at 0.05 level of significance.

4.1.1. Changes in plant density and cover over the long term (1972-2003) period.

Generally the density and cover for individual species and functional groups were related to the interaction of the time and grazing treatment or time and block (Tables 1 and 2). Because of limited degrees of freedom in the long term analysis, the three-way interaction could not be included, only the two-way interaction terms could be included. For example, over the 32 year period the density of perennial grasses fluctuated without showing a consistent response to the grazing treatment: in 1975 density was least in the YL treatment, in 1991 there was no difference among grazing treatments, and in 2000 YL was different from only one SR treatment (Tables 1 and 3). Shrubs density differed between blocks from 1975 to 2000, but did not differ in 1972 and 2003 (Tables 1 and 4).

Long-term shrub cover was not related to grazing system or block, but it did vary over time: it increased slowly between 1975 and 1984, persisted at that high level until 1994 when it declined and remained at values present in 1981 (Tables 2 and 5).

Table 3. Means comparison of perennial grass density (plants/m^2) by year, block and grazing treatment (using Tukey-Kramer HSD).

Variable	Year										
	1972	1975	1978	1981	1984	1991	1994	1997	2000	2003	Average
Grazing systems											
Yearlong	8.72b	8.52b	8.48c	7.21b	11.84b	14.31	13.22	10.36b	9.23b	7.09b	9.90
SR1	24.93a	18.86	15.77ab	12.76a	19.53ab	28.62	14.08	15.47b	11.30ab	12.48b	17.38
SR2	12.03b	11.19	11.80bc	10.14ab	13.53ab	22.95	20.66	12.32b	11.61ab	14.46ab	14.07
SR3	18.93a	34.23	23.11a	11.86ab	20.48a	26.94	18.88	32.29a	18.88a	25.60a	23.12
Block											
II	18.49a	19.30a	17.48a	13.03a	17.66a	27.03a	20.58a	18.79a	13.58a	13.18	17.91
III	11.42b	11.15b	8.12b	6.32b	12.91b	16.16b	10.60b	11.07b	9.56b	13.67	11.10
Average	15.54	15.89	13.56	10.23	15.67	22.49	16.41	15.56	11.90	13.39	15.06

Means followed by different letters are significantly different at the 0.05 level

Table 4. Means comparison of total shrub density (plants/m^2) by year, block and grazing treatment (using Tukey-Kramer HSD).

Variable	Year									
	1972	1975	1978	1981	1984	1991	1997	2000	2003	Average
Grazing systems										
Yearlong	1.12	3.71	2.52	2.39	1.72	2.23	0.90	0.79	0.70	1.79
SR1	0.93	5.18	1.71	2.58	1.42	1.22	0.86	0.71	0.54	1.68
SR2	1.30	5.26	1.82	2.82	2.04	1.58	1.68	1.07	1.10	2.07
SR3	1.24	1.99	1.72	1.88	0.99	1.30	1.00	1.35	1.16	1.41
Block										
II	1.33	2.90b	1.57b	1.79b	1.33b	1.18b	1.03b	0.85b	0.95	1.44
III	0.87	6.22a	2.56a	3.45a	2.03a	2.28a	1.26a	1.05a	0.69	2.27
Average	1.14	4.29	1.98	2.49	1.62	1.64	1.13	0.93	0.84	1.78

Means followed by different letters are significantly different at the 0.05 level

Table 5. Means comparison of shrub cover (%) by year, block and grazing treatment (using Tukey-Kramer HSD).

Variable	Year									
	1975	1978	1981	1984	1991	1994	1997	2000	2003	Average
Grazing systems										
Yearlong	11.43	17.42	21.69	29.66	27.32	20.87	15.69	21.00	18.31	20.38
SR1	12.16	16.37	19.67	27.09	26.93	20.21	15.21	19.62	16.96	19.36
SR2	13.13	20.22	23.71	33.48	30.94	23.30	17.74	20.39	18.93	22.43
SR3	15.09	20.47	24.11	38.08	38.41	21.66	19.58	25.43	19.97	23.64
Block										
II	13.40	20.26	23.95	31.16	33.68	24.60	18.45	23.69	21.02	23.36
III	11.61	15.78	19.49	27.94	24.62	17.18	14.32	17.54	14.68	18.13
Average	12.65c	18.39bc	22.08b	29.82a	29.90a	21.50b	16.72bc	21.12b	18.37bc	21.17

Means followed by different letters are significantly different at the 0.05 level

4.2. The effects of avoiding pseudoreplication on detecting effects of 4 grazing treatments on short term changes in plant density and cover.

By avoiding psuedoreplication, it was not possible to detect a grazing treatment or grazing treatment by time interaction, and only time was significantly related to the response variables of density and cover for the species studied (Table 6 and 7). The large reduction in importance of grazing in the dynamics of the vegetation was largely a result of reducing the sample size from 120 transects to 12 pastures.

It is interesting to note that when we converted the data sets to pasture averages, most of the data became normally distributed. Eight of the raw data out of 17 became normally distributed compared to only 1 data set when transects were used as the sample (experimental) units. Nonetheless, there were still differences in the results between the ranked and raw data (Tables 6 and 7).

Table 6. The P-values from repeated measurements analysis of grazing treatments done on raw and ranked data of plant density while avoiding pseudoreplication.

	Time	Grazing treatment	Time*block	Time*grazing treatment
Burroweed				
raw	0.055	0.803	0.241	0.604
ranked	0.015	0.889	0.214	0.385
Calliandra				
raw	0.112	0.468	0.261	0.724
ranked	0.026	0.280	0.205	0.420
Cholla				
raw	0.746	0.909	0.765	0.895
ranked	0.741	0.852	0.757	0.941
Prickly pear				
raw	0.066	0.283	0.103	0.522
ranked	0.069	0.355	0.208	0.597
Grass				
raw	0.362	0.905	0.281	0.621
ranked	0.018	0.875	0.051	0.09
Native grasses				
raw	0.003	0.641	0.021	0.116
ranked	0.040	0.462	0.425	0.502
Non native grasses				
raw	0.132	0.167	0.260	0.767
ranked	0.023	0.643	0.161	0.825
Lehman lovegrass				
raw	0.128	0.172	0.251	0.765
ranked	0.023	0.643	0.158	0.828
Rothrock grama				
raw	0.062	0.349	0.160	0.511
ranked	0.021	0.107	0.146	0.518

Shading indicates highest significant interaction or main effect at 0.05 level of significance.

Using the ranked data, all species or species groups varied over time except cholla density, mesquite cover, and prickly pear cover and density. Errors associated with using the raw data included a Type I error for a block x time interaction for native grass density, and a time effect for mesquite cover; and seven Type II errors when the ranked data revealed significant time effects that were not recognized when using the raw data.

Table 7. The P-values from repeated measurements analysis of grazing treatments done on raw and ranked data of plant cover while avoiding pseudoreplication

	Time	Grazing treatment	Time*block	Time*grazing treatment
Shrubs				
raw	0.001	0.699	0.696	0.608
ranked	<0.001	0.651	0.615	0.424
Velvet mesquite				
raw	0.021	0.913	0.063	0.258
ranked	0.055	0.910	0.289	0.311
Burroweed				
raw	0.008	0.639	0.375	0.479
ranked	0.002	0.608	0.153	0.450
Prickley pear				
raw	0.188	0.727	0.343	0.753
ranked	0.260	0.855	0.305	0.796
Calliandra				
raw	0.079	0.386	0.266	0.326
ranked	0.036	0.158	0.580	0.595

Shading indicates highest significant interaction or main effect at 0.05 level of significance.

4.3. Comparing results of analyses addressing normality, sample independence, accounting for interactions and avoiding pseudoreplication in short term study period to Martin and Severson (1988) results.

We found similar means of density and cover of all plant species and functional groups to those reported by Martin and Severson (1988) except for total density of shrubs. Our results based on means comparison over blocks, time and grazing treatments were comparable to Martin and Severson (1988)'s results but the Tukey-Kramer method (Tables 8-10) was more conservative compared to Duncan's multiple range test used by Martin and Severson (1988). This was evidenced by fewer means that turned out to be significantly different.

Two- and three-way interactions dominated the repeated measurements analysis results, indicating evidence that focus on simple grazing treatment, block or time effects would be misleading (Tables 1 and 2). Martin and Severson (1988) however, reported that density or cover changes over time were a simple function of either grazing treatment

or spatial variation among blocks, and avoided discussion and depiction of any interactions among main effects. Our results of repeated measurements analysis of the raw data showed that 12 of the 17 variables had a significant 3-way (time x block x grazing treatment) interaction, indicating that changes in plant density and cover over time were influenced by both block differences and grazing treatments (Table 1 and 2). Repeated measurements analysis allowed us to show that plant response to grazing on the SRER is driven by more complex interactions than simple main effects. The three-way interaction is confirmed when trends by which means of response variables in grazing treatments and among blocks change over time (Tables 8-10). For example, the means of shrub density in 1972 started out with two grazing treatments (SR1 and YL) in two different blocks (Block II and III) being significantly different, but in all subsequent years there was no difference between any blocks, grazing treatments, or their combination (Table 9). This scenario is evidence of a time by grazing treatment by block interaction because the differences unique to combinations of block and grazing treatment that were apparent in the first year did not persist in later years.

Martin and Severson performed their analysis on raw data which was not normally distributed. This introduced a risk of making the Type I errors which could have result in management decisions being taken on the pretext that either grazing treatment and/or block influenced plant dynamics on the SRER when in fact there was no evidence of that. Unfortunately Martin and Severson did not report the results of the split plot analysis to allow us to compare directly how their result would differ from our repeated measurements analysis.

When pseudoreplication was avoided by performing repeated measurements analysis on pasture averages (Tables 6 and 7), the results we generated differed greatly from the reports of significant grazing system, block or time effects by Martin and Severson. While the results gained when avoiding pseudoreplication do justify Martin and Severson's interpretation of simple main effects without interactions, our results differs from their results by 1) evaluating and then rejecting interactions, 2) detecting only time effects and no block or grazing system effects on the dynamics of the vegetation.

Table 8. Means comparison of perennial grass density (plants/m^2) for block by grazing treatment combinations by year (using Tukey-Kramer HSD).

Block x treatment combination	Year				
	1972	1975	1978	1981	1984
I YL	28.17ab	41.44a	35.52a	39.80a	23.95a
I SR1	43.89a	47.80ab	38.38ab	47.45a	25.30a
I SR2	19.09abcd	24.41abc	19.70abc	18.22ab	15.79abc
I SR3	38.07ab	23.19abcd	25.94abc	23.28ab	19.64ab
II YL	13.15bcde	11.36bcd	11.26cde	9.90bc	11.36abc
II SR1	15.07cdef	16.31abcd	16.58bcd	13.48bc	20.29ab
II SR2	25.65ab	14.71abcd	18.29abc	16.38ab	17.32abc
II SR3	18.93abcd	34.23abcd	23.11abc	11.86bc	20.48ab
III YL	4.29f	5.68d	5.72e	4.52bc	12.30bc
III SR1	8.48def	6.31cd	6.91de	6.59c	6.01c
III SR2	23.50abc	22.81abcd	12.11cde	7.60c	19.77abc
III SR3	6.72ef	5.94cd	8.43de	4.98c	11.83abc

Means followed by different letters are significantly different at the 0.05 level

Table 9. Means comparison of shrub density (plants/m^2) for block by grazing treatment combinations by year (using Tukey-Kramer HSD).

Block x treatment combination	Year				
	1972	1975	1978	1981	1984
I YL	4.49ab	2.69	2.31	3.38	2.55
I SR1	2.53ab	2.17	1.58	1.98	1.86
I SR2	1.24ab	2.60	1.46	1.63	2.11
I SR3	3.29ab	3.97	2.21	3.70	3.93
II YL	1.45ab	3.55	1.87	1.99	1.21
II SR1	2.00a	5.36	2.06	2.81	2.39
II SR2	0.38ab	1.01	0.72	0.57	0.48
II SR3	1.16ab	1.91	1.41	1.74	0.85
III YL	0.60b	3.70	2.93	0.81	2.03
III SR1	0.65ab	5.36	1.93	3.04	1.77
III SR2	1.46ab	10.53	2.85	5.52	2.70
III SR3	1.65ab	4.46	5.36	3.48	2.29

Means followed by different letters are significantly different at the 0.05 level

Table 10. Means comparison of shrub cover (%) for block by grazing treatment combinations by year (using Tukey-Kramer HSD).

Block x treatment combination	Year			
	1975	1978	1981	1984
I YL	15.07	20.64ab	19.24abc	26.25abcd
I SR1	6.32	10.26b	12.75c	24.21cd
I SR2	19.28	25.64a	37.78a	37.30ac
I SR3	15.27	19.84ab	26.11abc	33.74abcd
II YL	11.55	20.97ab	26.81ab	36.32ab
II SR1	14.59	24.01ab	27.91abc	36.33abcd
II SR2	13.74	19.01ab	20.54abc	28.75abcd
II SR3	15.09	20.47ab	24.11bc	28.08bd
III YL	10.67	13.94ab	16.77bc	23.22bd
III SR1	13.91	19.86ab	23.12abc	35.23abcd
III SR2	9.17	11.60ab	18.23abc	24.15abcd
III SR3	24.30	31.30a	36.58ab	42.07abcd

Means followed by different letters are significantly different at the 0.05 level

5. Conclusion

Results from the comparison of raw versus ranked data show the importance of upholding the assumption of normality. Analysis based on non-normal data is likely to result in wrong inferences being reached thereby making either type I or type II errors.

Results from applying the repeated measures analysis, that accounted for the lack of temporal independence among the measures from permanent transects, revealed important interactions among the grazing treatment, block and time main effects. Interestingly, in the original reporting of these data, Martin and Severson ignored the issue of lack of independence, and failed to account for interactions among the main effects. As a result of these oversights, they misrepresented the vegetation dynamics as responding simply to grazing system, block, or time. In contrast, our analysis revealed that the norm was for significant 2-way and 3-way interactions among main effects. The three-way time by block by grazing treatment interaction shows evidence of both grazing system and spatial differences associated with blocks as important factors in determining plant dynamics on the SRER. Because blocking was based on different precipitation zone in the area, this three way interaction also implies that precipitation influences plant dynamics on the SRER. Although results showing interactions are more difficult to

interpret and apply in a management setting, they are more realistic and supportable because they do a better job of representing the nature of vegetation dynamics.

The fewer degrees of freedom that result when psuedoreplication is avoided reduced the power to detect differences in the vegetation dynamics that can be associated with either grazing treatment or block. In fact, with one exception, only the simple effect of time was related to vegetation dynamics when psuedoreplication was avoided. As a result, the strongest inference from this study, that which can be supported by the statistical analysis and proper representation of the experimental unit, is 1) on areas similar to the study pastures, either on the SRER or in similar environments, vegetation dynamics will be related to temporal fluctuations, and not the application of the SR grazing system or the environmental differences among the 3 blocks of pastures, and 2) within the confines of the 12 study pastures, vegetation dynamics are related to the 2 and 3-way interactions among grazing system, block, and time rather than simple, solitary relationships with the factors.

Management decisions based on such unsupported inferences in fragile semi-desert ecosystems could have serious undesirable ecological implications, and undermine confidence in scientific investigations. While the application of complicated statistical analysis may paint a less tangible picture of vegetation response to management practice, they are much preferred to a false sense of security that may come from overly simple and incorrect statistical analysis.

The availability of long term data greatly improved the understanding of the plant dynamics. Results from the short term study indicated a continuous gradual decline in perennial grass density and increasing shrub cover over time. However after 32 years of the experiment evidence of fluctuating grass density which is likely to be responding to climatic changes and some gradual decrease or stabilizing of shrub cover are emerging. Long term data is valuable in semi-arid ecosystems where response to management is likely to be slow and environmental variables become important driving factors of the ecosystem dynamics.

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00-218

Final Report
for last amendment

30 September 2005

Carl Edminster, Project Leader
Rocky Mountain Research Station
2500 South Pine Knoll
Flagstaff, Arizona 86001
928-556-2177 (voice, office)
928-380-5973 (voice, mobile)
928-556-2130 (fax)
cedminster@fs.fed.us (email)

Dear Carl:

Please consider the enclosed Final Report for the amendment to the Joint Venture Agreement No. 00-JV-11221615-218 entitled *Long-Term Response Of Vegetation To Management On The Santa Rita Experimental Range.* This specific amendment focuses on the development of a data access prototype.

We completed all the proposed tasks, and now have prototype databases and procedures to query them. This effort shows that there is much promise in developing the content metadata for a many elements of the Santa Rita paper archive, and that these metadata can facilitate many sophisticated queries of the database.

We would like to continue development and implementation of the development of these databases and their query on the worldwide web. To this end, we ask if there are resources available to support:

1) manual scanning and creation of PDF files of existing research study area paper files containing text, photos and maps so they can be added to the database structure created in our work reported here,

2) complete the acquisition of content metadata for the full set of 110 permanent photo stations using the metadata structure we developed in this effort, and

3) store the photos as binary large objects in a relational database and serve images using the content metadata developed for the images in the current digital database for the Santa Rita (http://cals.arizona.edu/srer).

I will call next week to follow-up on the possibility of gaining funding for these efforts. We want to continue the very important momentum gained by the completion of this current project.

Sincerely,

Mitchel McClaran
Professor of Range Management
Director of Research, Santa Rita Experimental Range

Enclosure

Final Report for Joint Venture Agreement No. 00-JV-11221615-218

Long-Term Response of Vegetation To Management On The Santa Rita Experimental Range

Prepared by
Mitchel P. McClaran, School of Natural Resources,
University of Arizona, Tucson, 85721

30 September 2005

Final Report for Joint Venture Agreement No. 00-JV-11221615-218

Long-Term Response of Vegetation To Management On The Santa Rita Experimental Range

Prepared by
Mitchel P. McClaran, School of Natural Resources,
University of Arizona, Tucson, 85721

30 September 2005

Background:

The purpose of this agreement is to analyze the consolidated, long-term vegetation measurement archives available for the Santa Rita Experimental Range, Arizona, in order to describe the responses of vegetation to management practices over periods of >40 years.

Established in 1903, Santa Rita Experimental Range (SRER) is the oldest range experiment station in the world. Initially, the U.S. Department of Agriculture, Bureau of Plant Industry were the primary organizations conducting research on the SRER, and later the Forest Service in cooperation with the University of Arizona. Federal legislation in 1988 transferred the SRER to the Arizona State Land Department and Arizona Senate Bill 1249 (38th Legislature) provided that the area would be used by the University of Arizona for, "ecological and rangeland research purposes..... until such time as the legislature determines the research use can be terminated on all or part of the lands."

Because written records of climate, vegetation change, livestock use and land use treatments as well as repeat photography have been collected on SRER since 1903, this database provides a long term record that is unsurpassed in the Southwest or the world.

The records include a combination of weather records; plant species composition measurements on more than 200 permanent plots; extensive land treatment studies; short term, usually small scale tests or observations; and over 110 permanent photography stations.

Objectives:

The general objective of this amendment is to provide increased access to natural resources data for the Santa Rita Experimental Range through the development of a prototype data access system. Such a searchable database would provide quick access to spatially organized information such as previous research activities, vegetation composition, soil composition, and repeat photography. The specific objective of this amendment is to develop a prototype computer application that allows users to perform spatial and logical query of selected repeat photography

points, rain gage locations, historic study areas and information associated with these themes that is currently available digitally.

This prototype will be used to attract funding to develop a searchable database of all known research activities on the Santa Rita Experimental Range, Arizona for the purposes of attracting and managing future research efforts.

Procedures:

1. Perform overall project planning to establish a conceptual level framework for the project.

2. Conduct an analysis to refine concepts into defined functions.

3. Develop a detailed systems design for the application.

4. Reformat the existing digital data on repeat photography points, rain gages, and historic study areas into a searchable relational database including: a) analysis of all existing digital data on selected repeat photo images, precipitation, and historic study areas, b) design a relational data structure that supports application query requirements, c) develop methodologies and procedures to migrate selected digital data from its various formats into a relational structure that will be linked to the existing feature datasets, d) document the final form of the integrated database.

5. Implement the design in a series of integrated applications.

6. Test the prototype application to ensure compliance with needs analysis.

7. Summarize the application development activities and refine future research requirements, including: a) development of integrated presentation materials that highlight the benefits and costs of this research application, and b) a refined description of research and support requirements necessary to create such a searchable database for the SRER.

Timetable for Accomplishing Procedures:

	DATE								
	2004						2005		
Procedure	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	X								
2	X	X							
3		X	X						
4		X	X	X	X				
Progress Report					X				
5					X	X	X		
6						X	X	X	
7								X	X
Final Report									X

Progress Made on Procedures by 30 September 2005:

1. Perform overall project planning to establish a conceptual level framework for the project.

   Completed.

   Overall project planning for the conceptual phase of the project is complete. The central concept is that of a web-based application and associated database that will support query and display of selected data and content for the Santa Rita Experimental Range (SRER). These data sets and content include:

   - Rain gauges and associated monthly precipitation records
   - Historic study areas and associated studies
   - Repeat photography and photo caption information

   Tasks and subtasks have been identified and are being refined for all project procedures. Personnel assignments have been made for both individual and group tasks. Target dates for design and development milestones have been established.

2. Conduct an analysis to refine concepts into defined functions.

   Completed.

   The functional requirements inform the design of the database and associated applications. These databases will be based on large integrated data types. Precipitation data will be normalized and stored in a relational database management system. Current approaches to storing and serving text and graphic information contained in digital and analog sources include Adobe's portable document (PDF) and hypertext markup language (html) formats.

   The application will be served through a standard html browser and support the display of user-selected geographic, tabular, and image data. The display and query interface will enable a remote user with a thin client to make both logical and spatial selections of feature classes and related records, photos, and documents from a web server.

   Precipitation data will need to be searched both spatially and logically. Spatial searches will support user-defined selection of rain gages. Logical query shall include temporal and precipitation value selections. Selected sets of precipitation data will be available for display and download to a client.

Historic study areas and their associated study information will be available for spatial and logical search. The geographic features shall be selectable by spatial and logical methods. Keyword relations will be developed for study document content.

Photographic images will be indexed for content and caption information. The images will be searchable by foreground content, date, location, and subject.

3. Develop a detailed systems design for the application.

Completed.

The conceptual response to the functional requirements of the application(s) has been reviewed. The system will be of a modular design with different applications supporting specific data processing and file service requirements. The main database applications will run in an SQL-compliant DBMS that will support both the spatial (mapping) needs and the processing of content queries on studies, precipitation data, and photographic images. Microsoft's ActiveX Data Objects (ADO) will be used to link applications programs with an SQL-compliant database.

The geographic feature classes representing the historic study areas and rain station locations will be provided to users through and Internet Map Service (IMS) developed on ESRI's IMS technology. The IMS technology supports separate image services for both data sets through an html client.

Internet services will be provided from a server located at the Advanced Resource Technology (ART) facility in the School of Natural Resources. The reformatted data sets will reside on servers at ART.

4. Reformat the existing digital data on repeat photography points, rain gauges, and historic study areas into a searchable relational database including: a) analysis of all existing digital data on selected repeat photo images, precipitation, and historic study areas, b) design a relational data structure that supports application query requirements, c) develop methodologies and procedures to migrate selected digital data from its various formats into a relational structure that will be linked to the existing feature datasets, d) document the final form of the integrated database.

a) analysis of existing data

Completed.

The photographic images, in the Tagged Image File Format (tiff) were

available online from the Santa Rita Experimental Range Website at http://cals.arizona.edu/SRER/photos.html. At this site were found over 700 images from 117 repeat photography locations. The photography dates from 1902 through 2003. The data varies in both temporal and spatial content. There are variable time periods between some of the images, sites were photographed at different times of year, some locations were added after the repeat photography had started, and some have not been continually photographed. Additionally the number of photos and their direction is not consistent through the set. Some repeat locations have as many as 30 images associated with them, while many had as few as four images. Many of the repeat photo images for a given site had captions associated with them as html text on the website http://cals.arizona.edu/SRER/photos.html. All the images contained consistent information on station number, image date, and relative direction. Most have camera technical specifications.

The historic study information consisted of an existing digital polygon feature class stored in a geographic information system at ART. The feature class had been previously digitized from a hardcopy map provided by Dr. Mitchel McClaran, Director for Research at SRER. The map contained known study site locations for research projects completed between 1902 and 1939. In addition, content information about studies at 2 locations was made available for assessment and automation. This information included photographic prints, notes, and detailed field maps.

The precipitation data was obtained from the SRER website (http://cals.arizona.edu/SRER) as an Excel Spreadsheet file. The file contained monthly precipitation data from 1992 through 2004. The data in the spreadsheet was structured as a table with the following column definitions:

DATA FILE LAYOUT: PRECIPITATION
(FILE: precip.xls)

COL.	ITEM NAME	ITEM WIDTH	DATA TYPE	NUM DEC	ITEM DESCRIPTION
A	STATION	5	TEXT	-	Rain station (gauge) name code.
B	YEAR	4	NUMBER	0	Year of precipitation measurement.
C	JAN	8	NUMBER	0	January precip. in 100ths of inches.
D	FEB	8	NUMBER	0	February precip. in 100ths of inches.
E	MAR	8	NUMBER	0	March precip. in 100ths of inches.
F	APR	8	NUMBER	0	April precip. in 100ths of inches.
G	MAY	8	NUMBER	0	May precip. in 100ths of inches.
H	JUN	8	NUMBER	0	June precip. in 100ths of inches.
I	JUL	8	NUMBER	0	July precip. in 100ths of inches.
J	AUG	8	NUMBER	0	August precip. in 100ths of inches.
K	SEP	8	NUMBER	0	September precip. in 100ths of inches.
L	OCT	8	NUMBER	0	October precip. in 100ths of inches.
M	NOV	8	NUMBER	0	November precip. in 100ths of inches.
N	DEC	8	NUMBER	0	December precip. in 100ths of inches.

The data were organized by station name and year. The data set contained observations for 75 rain gage stations on the SRER.

b) *design of relational database*

Completed.

The current application is supported by several databases. The database design activities produced a relational database for content metadata for photographic images. The design process was an implementation of standard database design procedures starting with the development of an Entity-Relationship Model for the content metadata. The logical structure of the image content metadata is contained in Appendix A. Content for historic study areas is stored in the Adobe Portable Document Format. The documents are associated with a geographic feature database based on a georelational model. The precipitation data was restructured into a relational format for use in georelational model.

c) *migration methodologies*

Completed.

Data and content related to repeat photography, precipitation data, and historic study areas was automated and converted for use in the application.

The migration of the repeat photo station images involved the conversion of images from one digital file format to another and the development of a relational database to store content metadata for each image. Image files in the Tagged Image File Format (tiff) were obtained from the SRER website (http://cals.arizona.edu/SRER/photos.html) and converted to the JPEG File Interchange Format (JFIF) and stored as files with the jpg extension. All photo captions available as html text were parsed from the SRER website and loaded into the content metadata relational database. Content metadata was derived for a small number of images for the purposes of interface testing. The metadata was entered through a developed content metadata input form developed using Visual Basic for Applications (VBA) and running in Microsoft Access.

Migration of the historic study area data involved the processing of two

types of source data: an existing polygon feature class stored in a GIS database, and various forms of hardcopy information associated with each plot. Content for the historic study areas was automated from photographic prints, notes, and study maps. The content was scanned using a Hewlett-Packard electronic scanner into jpeg format files. The content was organized by study area within an Adobe Portable Document Format (PDF) file. The existing digital feature class for historic study areas was amended to include a reference to the fully qualified file name of each PDF file, so that the content could be associated with feature for data service.

d) *documentation of database*

Completed.

The developed data service application is comprised of a relational database and a GIS database and related content in the form of photographic, map, and data images.

In the case of the repeat photography data, the relational database was designed to store and manage content metadata for the repeat photographic images. The logical structure is illustrated in Appendix A. The design was implemented in Microsoft Access 2003 as a series of related tables. An image of the relationships diagram of the database is shown in Appendix B. The attributes of these tables store information related to image content in the foreground and background of the image, as well as the original caption text. The photo images were stored as jpg files on a local file system. References from the content metadata attributes to the images were stored in the database.

The GIS database consists of feature data class representing location and attribute information for historic study plots and rain stations. These feature classes were obtained in the ESRI shapefile format from the GIS data library for the SRER website at http://cals.arizona.edu/srer. The metadata for these two feature classes is found in Appendix C.

Content related to the historic study area feature class was stored in the Adobe PDF format and organized by study. Each PDF file could contain scanned map images, field notes, and photographs related to a feature in the GIS database. In our case, the prototype has provided for the automation of three studies.

5. Implement the design in a series of integrated applications.

Completed.

The integration function of the application was assigned to the internet services layer. An html interface was designed to provide orientation to the database and data set selection. This interface was chosen to allow flexibility in the development and deployment of new searchable data sets as they become available. The application homepage (http://codd.art.srnr.arizona.edu/srerjva) is used to access the respective query environments for repeat photography, historic study areas, and precipitation data.

6. Test the prototype application to ensure compliance with needs analysis.

Completed.

The purpose of the prototype was to demonstrate a potential through a designed interface and data structure. The inclusion of formalized testing and assessment methodologies was not part of the project scope. As a prototype development, the testing at selected levels was qualitative, with inputs from ART staff and study participants, Dr. Mitchel McClaran, Director for Research SRER and Mark Heitlinger, Manager SRER. The components of the application were tested separately at different levels of development.

The repeat photography data set design was developed through input of the study participants. Design issues included the approach to development of content metadata, development of domains for critical content metadata elements, and query support. For the development of domain values for the photographic content metadata, the process involved reviewing and incorporating input from both study participants and the staff at ART. The result was a discrete list of values for each of the content metadata elements derived from each photo. These values were used to populate the content metadata database used in the project.

The study participants also assisted in the development of potential query situations that the proposed system could support. Through discussion, a concept for supporting queries on the three data sets was developed and implemented.

The web publishing of the prototype query interface is available at http://codd.art.srnr.arizona.edu/srerjva and provides a method of obtaining feedback from a wider audience. This information would be necessary to continue the development of the application.

7. Summarize the application development activities and refine future research requirements, including: a) development of integrated presentation materials that highlight the benefits and costs of this research application, and b) a refined description of research and support requirements necessary to create such a searchable database for the SRER.

Completed.

Application Development Summary

The application consists of a web-enabled interface that facilitates the selection and query of information from three related data sets on the Santa Rita Experimental Range; repeat photographic images, monthly precipitation data, and historic study area information. The development began with the establishment of a conceptual framework for the entire application. In this case, the application domain was identified as access to data sets collected on the SRER. The access includes visualization and query support for selected data sets. Logical structures for representation and access to the information were developed from the concepts. The identified data sets each had distinctive data types and formats. Functions that were identified that could meet the query requirements of the application. In the next phase of the project alternative architectures and applications were considered. In our current implementation, the selection of these architectures and platforms was more influenced by the skill set of our staff than from access to tools.

Decisions about the architecture and function of the application were done with a full understanding of the structure of the candidate data sets. Each set required some type of conversion or reformatting.

The details of the system architecture such as specific software packages and file formats are not meant to be demonstrative of the final format of a fully-functional data query service for SRER. In the interest of rapid development and prototyping, existing well-know application suites (such as Microsoft and ESRI) were selected to implement and demonstrate the potential of the system. The focus then was proof of design concept over detailed tool selection and customization.

The prototype interface is served from a single Intel-based workstation running Microsoft Internet Information Service (IIS) on a Windows 2003 Server Web Edition operating system. The interface can be viewed at http://codd.art.srnr.arzona.edu/srerjva.

Future Research Direction

The process of determining the final form and structure of the web-enabled search interface provided opportunities for discovery and assessment of alternative access methods and data structures. At various phases of project development potential directions for future research and development were investigated. This section of the report will summarize those findings.

There are two data structure approaches for imagery that were investigated for application in the SRER system. The first of these employs Resource Description Framework (RDF) metadata stored inside JPEG files. The format in, conjunction with JAVA applications and standard HTTP, has been proposed by the World Wide Web Consortium (W3C) (http://www.w3.org) as a method of storing and retrieving content metadata stored inside JPEG files. Because images are commonly stored in this format, it would seem useful to store content metadata inside the files themselves. W3C has developed custom applications to enter and query content metadata as formatted text within the JPEG file. Currently, there are three metadata content schemas supported including the Dublin Core Metadata, which is intended, specifically, to facilitate the location of electronic data. Content of this schema, or others, can be adapted to meet the structure of our content metadata.

The second approach for handling the repeat photography imagery involves the storage of the images, themselves, as binary large objects (BLOBS) *inside* a relational database. Under this approach the images would be converted from the JPEG format into a relational data structure running inside some kind of Relational Database Management System. Because the content metadata is already stored inside an SQL-compliant relational database, this method would store the image as part of the data record for each photo. This would result in the consolidation of hundreds of separate photo image files into one relational database file.

In terms of preferring one of these approaches over another, it becomes apparent that both approaches have benefits. Storing the content metadata *inside* the photo image file assures the associability of the content metadata with the image file – to have the image is to have the content metadata. Storing the image as a BLOB in a database also associates the image with the content metadata in a relational database. All images are stored in the relational database -- to have the database is to have all the images and all the content metadata. Inasmuch as the SRER repeat photo archive is stored and searched as an integrated unit it may be reasonable to store the image as a BLOB in the database. If, however, the images were to be available for service at user request, it would seem beneficial to provide the images in a common format (JPEG) with content metadata associated with them (RDF).

For the rain station and historic study area data, an improvement in the system performance through the use of spatial data object handlers would facilitate a wider range of query functions. In particular, we have evaluated the use of Spatial Database Engine (SDE) technology from ESRI as a method of serving geographic features and related data. In the case of the precipitation data, this approach would support the association of more complex relational databases with the geographic features, which would facilitate more advanced query functions such as on-the-fly period summaries. The use of SDE would also provide functions for serving raster data sets. Because the SDE is built upon common commercial RDBMS, this would help with the integration of all existing photo and content metadata for the SRER.

The current implementation of the query on historic study area information provides for a priori grouping of various information types – images, text, and maps—served as PDF files. The access to information contained in these types would be greatly facilitated by the conversion of text from content to data. We have begun evaluation of storage of unstructured content as structured data using the XML standard. Because all types of content (text reports and images) can be stored in XML format, this content would be searchable and accessible via the Internet. The process would involve automating legacy material, such as project reports, converting it to text using optical character recognition, and converting it into XML format. In this way, content could be accessed at any level, from the report down to the word level. There are industry standard languages like XPATH (http://www.w3.org/TR/xpath) and XQuery (http://www.w3.org/TR/xquery) that can be used to search and retrieve the content stored as data in an XML format. Specific words or strings could be searched and retrieved by a user at the document or paragraph level. This approach would not only make content machine-processable, but allow for content reuse and adheres to established standards for storage and retrieval.

On the application level, we have evaluated the use of server-side GIS data processing as a method of extending the query capabilities of the system to include spatial queries based on standard GIS concepts like proximity and containment. In order for us to provide such functionality to an end user with a browser client, we will need a server side application that can present functions and display results through our existing Internet Map Servers for SRER. To this end, we recommend researching the installation and configuration of ESRI's ArcGIS Server suite. This group of applications has several benefits: it reads and writes our spatial data in its native format, it interacts with the IMS, and it is developed using tools and protocols that we are already familiar with. The inclusion of server-side GIS analytical functionality would enable a user to make more complex queries of the wealth of data and information for the SRER. For example, subsets of vegetation production records could be requested on the fly

for all records in a specified set of pastures.

We continue to explore and evaluate data structures, information architectures, and applications that can be used to develop the SRER NRIS towards its logical conclusions.

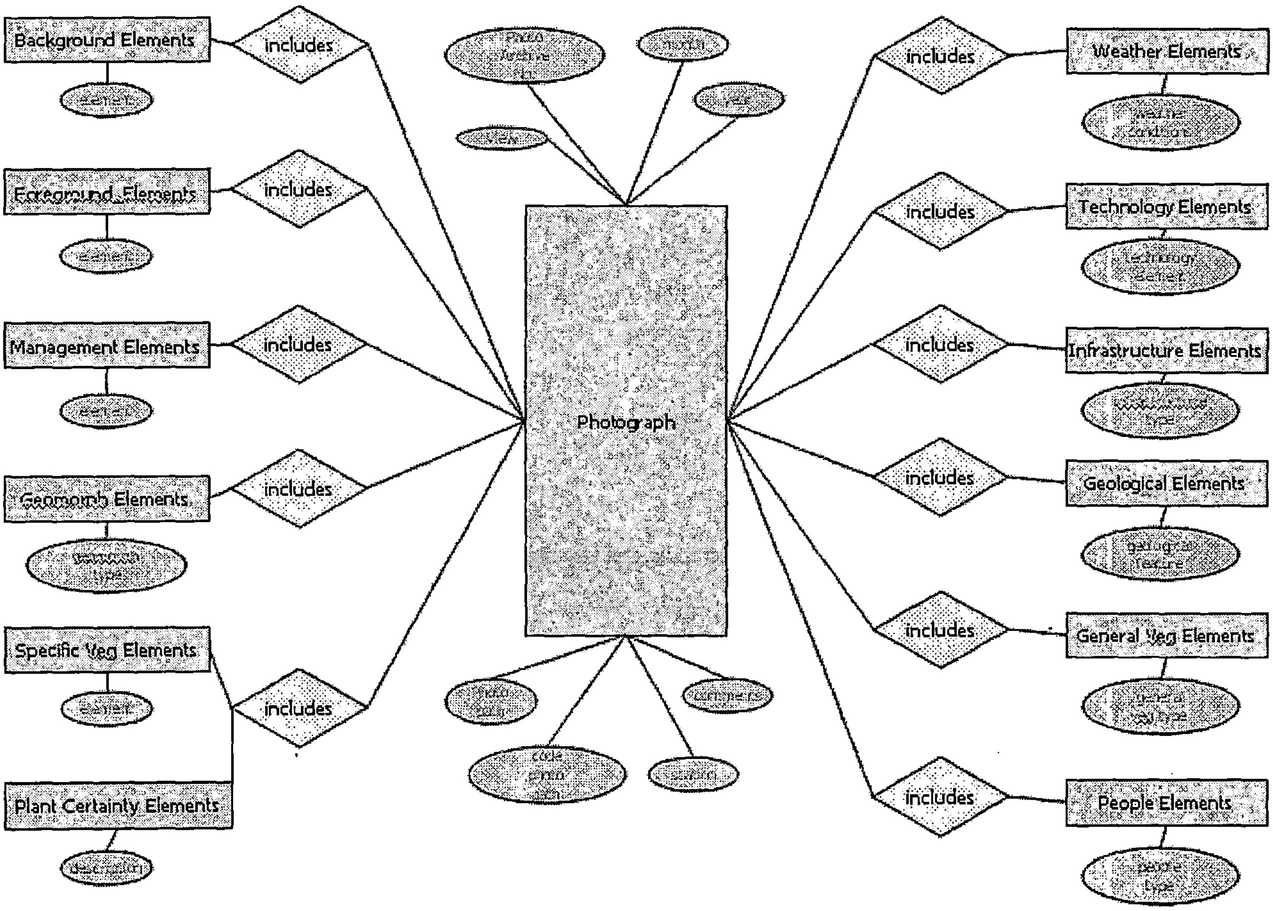
Final Report for Joint Venture Agreement No. 00-JV-11221615-218

Long-Term Response of Vegetation To Management On The Santa Rita Experimental Range

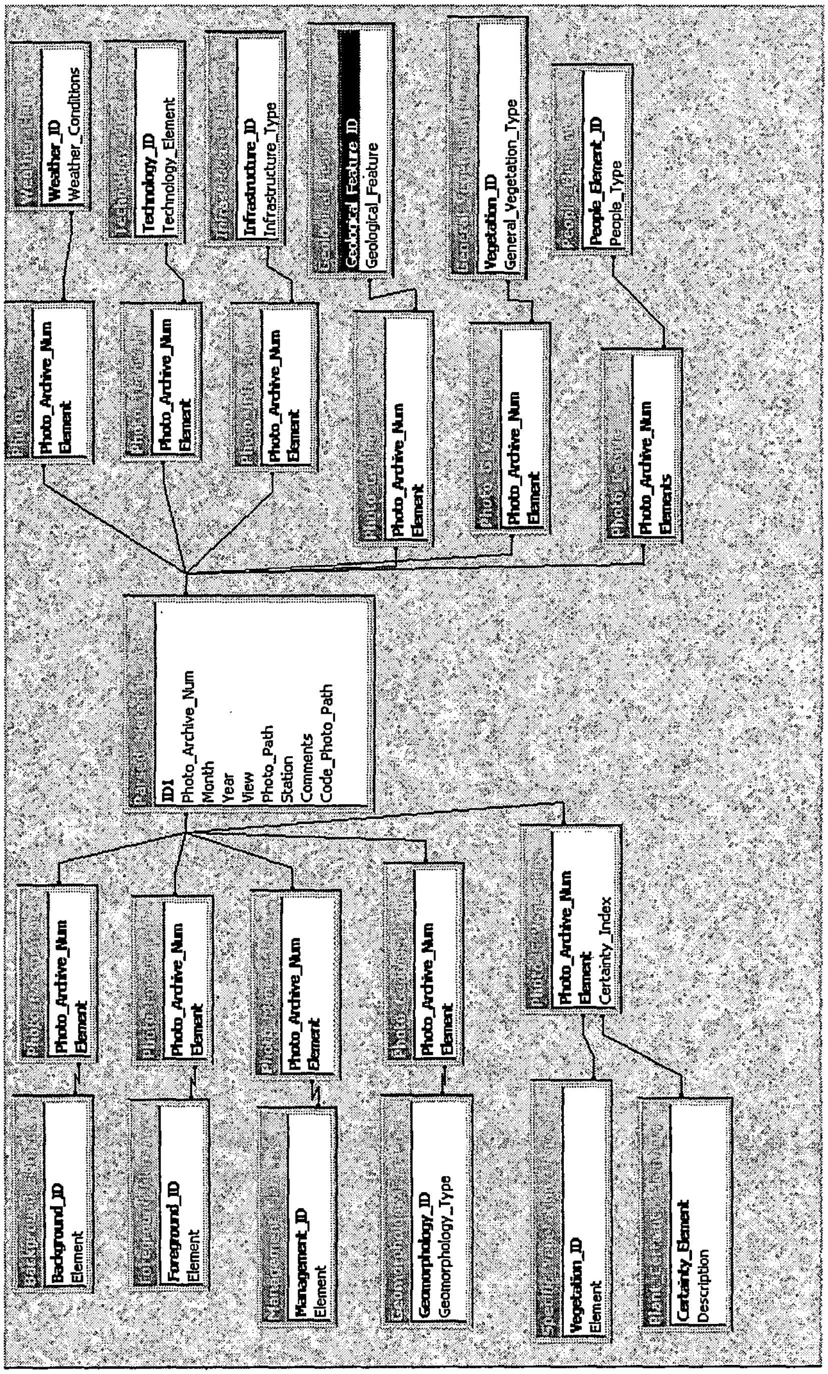
Prepared by
Mitchel P. McClaran, School of Natural Resources,
University of Arizona, Tucson, 85721

30 September 2005

Appendix A
Entity-Relationship Diagram Photographic Content Metadata



Appendix B
Relationship Diagram Photographic Content Metadata



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30 September 2005

Appendix C
GIS Feature Class Metadata

rain_sta

Identification_Information:
Citation:
Citation_Information:
Originator:
REQUIRED: The name of an organization or individual that developed the data set.
Publication_Date:
REQUIRED: The date when the data set is published or otherwise made available for release.
Title: rain_sta
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage:
\\Famulus\famdata\srer_jva\AA_ims\rain_sta.shp
Description:
Abstract:
Rain_sta A point feature class of rain gage locations on the Santa Rita Experimental Range
Purpose:
Data set was developed to link long-term precipitation records with rain gage ground locations
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: unknown
Currentness_Reference: publication date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -110.961563
East_Bounding_Coordinate: -110.785213
North_Bounding_Coordinate: 31.917501
South_Bounding_Coordinate: 31.761110
Keywords:
Theme:
Theme_Keyword_Thesaurus:
REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword:
REQUIRED: Common-use word or phrase used to describe the subject of the data set.
Access_Constraints: There are no access constraints
Use_Constraints: There are no use constraints, except for acknowledgement
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.1.0.722

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Entity point
Point_and_Vector_Object_Count: 75

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 12
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -111.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000032
Ordinate_Resolution: 0.000032
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: rain_sta
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: STATION
Attribute_Definition: primary key field
Attribute:
Attribute_Label: STATION___
Attribute_Definition: full name of rain station
Attribute:
Attribute_Label: X_COORD
Attribute:
Attribute_Label: Y_COORD

Distribution_Information:
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 0.002

Metadata_Reference_Information:
Metadata_Date: 20050923
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: The University of Arizona
Contact_Person: Craig Wissler
Contact_Address:
Address_Type:
REQUIRED: The mailing and/or physical address for the organization or individual.
City: REQUIRED: The city of the address.
State_or_Province: REQUIRED: The state or province of the address.
Postal_Code: REQUIRED: The ZIP or other postal code of the

address.
Contact_Voice_Telephone: 520-621-9588
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

---

studyareas

Identification_Information:
Citation:
Citation_Information:
Originator:
REQUIRED: The name of an organization or individual that developed the data set.
Publication_Date:
REQUIRED: The date when the data set is published or otherwise made available for release.
Title: studyareas
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage:
\\Famulus\famdata\srer_jva\AA_ims\studyareas.shp
Description:
Abstract:
A polygon feature class of historic study areas on the Santa Rita Experimental Range
Purpose: This was developed as a part of the larger SRER GIS database
Supplemental_Information:
Original GIS data developed at the Adavnced Resource Technology facility, School of Natural Resources, University of Arizoan
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: unknown
Currentness_Reference: publication date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate:
REQUIRED: Western-most coordinate of the limit of coverage

expressed in longitude.
East_Bounding_Coordinate:
REQUIRED: Eastern-most coordinate of the limit of coverage expressed in longitude.
North_Bounding_Coordinate:
REQUIRED: Northern-most coordinate of the limit of coverage expressed in latitude.
South_Bounding_Coordinate:
REQUIRED: Southern-most coordinate of the limit of coverage expressed in latitude.
Keywords:
Theme:
Theme_Keyword_Thesaurus:
REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword:
REQUIRED: Common-use word or phrase used to describe the subject of the data set.
Access_Constraints: There are no access restraints
Use_Constraints: There no use restraints with citation.
Data_Set_Credit: ART
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.1.0.722

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 172

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: studyareas
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape

Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: AREA
Attribute:
Attribute_Label: PERIMETER
Attribute:
Attribute_Label: X_
Attribute:
Attribute_Label: X_ID
Attribute:
Attribute_Label: PLOTNUM
Attribute:
Attribute_Label: NEWPLOT_
Attribute_Definition: alpha version of plot identifier
Attribute:
Attribute_Label: STAREAURL
Attribute_Definition: stores URL data

Distribution_Information:
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 0.025

Metadata_Reference_Information:
Metadata_Date: 20050923
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: The University of Arizona
Contact_Person: Craig Wissler
Contact_Address:
Address_Type: mailing address
Address: BSE 325
City: Tucson
State_or_Province: Arizona
Postal_Code: 85721
Contact_Voice_Telephone: 520-621-9588
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Extensions:
Online_Linkage:
<http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
